

MEGARIPPLE MECHANICS

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Award #: N00014-96-1-0072

LONG-TERM GOAL

To understand the physics of sediment transport by waves and currents and to use that understanding to predict the evolution of nearshore bathymetry given the nearshore fluid velocity field and seafloor sedimentology and stratigraphy. A secondary goal is to interpret the environment of deposition and the offshore wave climate from the sedimentary record.

SCIENTIFIC OBJECTIVES

Present objectives are to identify characteristic bedform patterns and their modes of evolution in the nearshore environment at Duck, North Carolina using side-scan sonar images; to describe bedload transport over non-planar bed geometries, with particular application to megaripples; and to generate computer simulation models for evolution of nearshore morphology.

APPROACH

Field observations motivate laboratory studies of bedload transport and bedform evolution under controlled conditions, which are in turn used to develop and test both discrete-particle and cellular automata computational models for bedload transport and bedform evolution.

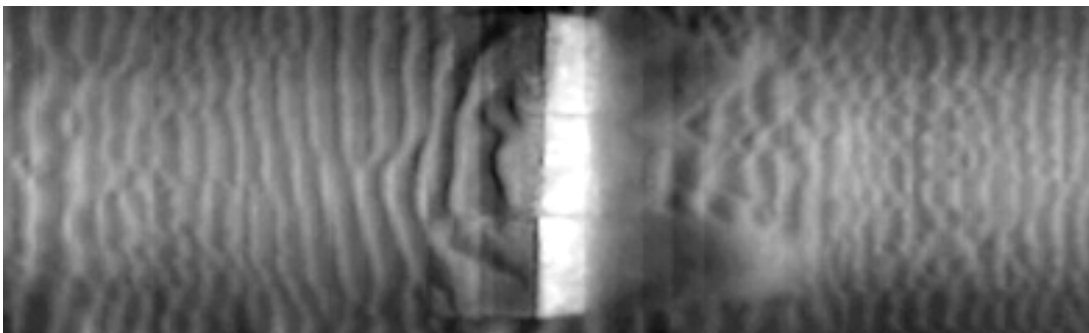


Figure 1. Nearshore wave-ripple patterns in the vicinity of a single channel-spanning fixed megaripple bedform in a 2.4-m-wide laboratory wave channel. Waves propagate from left to right. Flow irregularities induced by the megaripple form produce a high areal density of imperfections immediately onshore (right) of the megaripple. We hypothesize that interactions between such imperfections may initiate new megaripples.

Report Documentation Page				Form Approved OMB No. 0704-0188	
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1. REPORT DATE 30 SEP 1997		2. REPORT TYPE		3. DATES COVERED 00-00-1997 to 00-00-1997	
4. TITLE AND SUBTITLE Megaripple Mechanics				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) North Carolina State University, Department of Marine, Earth and Atmospheric Sciences, Raleigh, NC, 27695				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 4	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

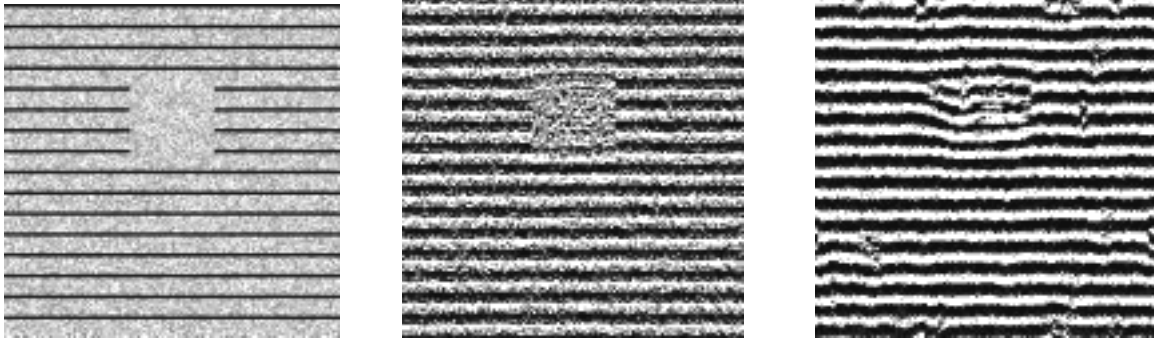


Figure 2. Time evolution of a simulated nearshore wave ripple field having a smooth sand patch from which ripples have been removed.

A sequence of snapshots from a cellular-automata simulation of ripple formation under nearshore wave conditions is shown above (Figure 2). These simulations depict the evolution of a small field of ripples in which a patch of existing ripples has been removed and subsequently reforms. The simulations correspond directly to physical experiments performed in the wave channel at Scripps Institution of Oceanography. Time progresses from left to right in the sequence. Darker areas correspond to higher topography; the black lines in the first frame are the crests of artificially tall, linear ripples. The mottled gray background is a randomly bumpy sand surface having small topographic deviations from a plane, much like a sand surface which has been flattened by hand. The spacing between the initial ripple crests is about 10 cm.

Immediately after “turning on” the waves, which propagate toward the top of the page, the initially sharp ripple crests are diffused, and incipient ripples can be seen in the smooth patch. These simulated ripples develop imperfections in the otherwise regular two-dimensional geometry in much the same manner as real ripples. The migration rates of such imperfections as ripple terminations and bifurcations are roughly three times the migration rates of undisturbed ripples, in approximate agreement with recent theoretical predictions of imperfection migration rates (Werner and Kocurek, 1997)

WORK COMPLETED

Development of side-scan sonar hardware and software for use in the SandyDuck ‘97 Coastal Field Experiment. The side-scan sonar and data-acquisition hardware are mounted on the three-legged surf zone surveying apparatus called the CRAB, enabling detailed acoustic images of the seafloor to be obtained in the surf zone to depths of 6 to 8 m even in the presence of waves up to about 2 m in height (Figure 3). Graduate student Peter Dickson drove the CRAB and directed field studies during the experiment.

Cellular automata simulation models have been developed (Dickson and Drake, 1996) to describe the topological evolution of bedform patterns. Such simulations replicate a number of pattern evolution phenomena documented in laboratory studies of bedform pattern initiation and evolution conducted in a large wave channel at the Scripps Institution of Oceanography. Video-imaging techniques

engineered by graduate student Heinz Seltmann, Jr. were used to document patterns and their response to perturbations generated by the presence of megaripples.

Graduate student Joe Calantoni is exploring effects of fluid model parameters in on-going computational studies of bedload transport phenomena using discrete-particle models at the NAVO High Performance Computing Facility.

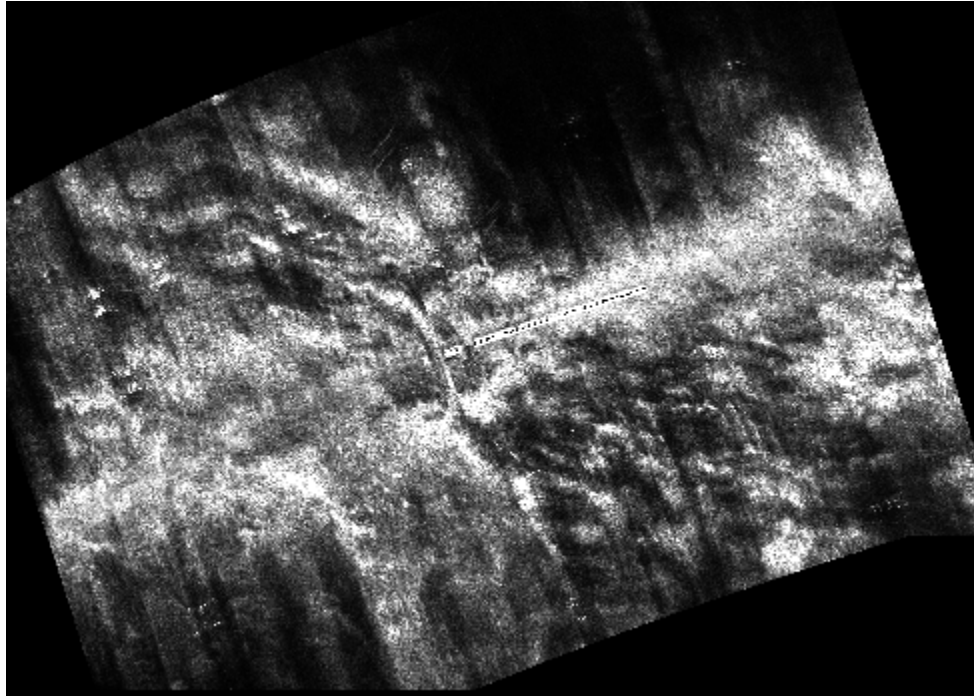


Figure 3. Side-scan sonar mosaic from Duck, North Carolina obtained during the SandyDuck '97 Coastal Field Experiment. North is up, the shoreline is to the southwest, and the width of the image (from northwest to southeast) is 100 meters. Whiter areas in the image indicate greater return of acoustic energy, which may correspond to geometric bed features or bed sediment grain-size characteristics or both. The left-hand side of the image lies just inside of a shore-parallel linear bar about 150 m from the shoreline. The light-colored, roughly linear mottled feature running diagonally across the image may be a rip channel.

RESULTS

SandyDuck '97 is presently underway, and we expect to spend the remainder of the year analyzing images acquired during the experiment, and incorporating observations into a plan for generating and testing cellular-automata models.

We have demonstrated that bedform patterns generated using cellular-automata models for the topological evolution of ripples and ripple imperfections are remarkably robust to changes in transport laws. This is significant because initial work used computationally-intensive algorithms, which threatened to limit the overall scope of our research effort. Since complex algorithms can be

well-approximated by much simpler algorithms, we are able to address much larger problems, both in spatial as well as temporal extent.

Particle-image-velocimetry (PIV) studies of bedload transport processes have shown the utility of a two-camera approach to the problem of obtaining the velocity field in the presence of large velocity gradients in the flow. Such gradients are always present near the bed in sediment-transporting flows, and have limited the application of PIV techniques to nearshore problems. The video/laser/data acquisition synchronization technique can be extended to multiple cameras.

Discrete-particle models for bedload transport are much less sensitive than previously thought to variations in a model parameter which relates the length scale of the smallest sediment-moving turbulent eddies to the volume concentration of particles in the bedload layer. We have developed a physical explanation for selecting that parameter, which has been an unsatisfactory free parameter in our model.

IMPACT/APPLICATION

We expect that the results of our SandyDuck field work will provide a significantly enhanced synoptic picture of surf zone bed geometry, which will be of much value to other SandyDuck investigators. The spatial extent of side-scan coverage obtained in the surf zone greatly exceeds any previous work at Duck or elsewhere, as does the near-daily temporal resolution of our imagery.

RELATED PROJECTS

SandyDuck '97 side-scan sonar studies were performed in collaboration with ONR investigators E. Thornton and E. Gallagher. Additional side-scan and shallow seismic geophysical studies in the Duck vicinity, supported by the Army Research Office, Terrestrial Sciences Program, provide geological context useful for this work and other ONR-supported work at the Duck, North Carolina Field Research Facility.

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Werner, B. T. and Kocurek, G., 1997, Bed-form dynamics: Does the tail wag the dog?, Geology, v. 25, p.771-774.

<http://www2.ncsu.edu/ncsu/pams/meas/faculty/drake/drake.html> (Drake home page, with links to ONR-supported research activities)